tinued at Portsmouth. My Lords desire by the establishment of the College, to give to the executive officers of the navy generally every possible advantage in respect of scientific education; but no arrangements will be made at all prejudicing the all-important practical training in the active duties of their profession. The object of securing, in the interest of the naval service, the highest possible scientific instruction is, in the opinion of my Lords, most effectually to be attained by bringing together in one establishment all the necessary means for the higher education of naval officers and of others connected with the navy. . . . Complete courses of study suitable for the different classes of students admitted will be organised, and will be carried out by professors, lecturers, and instructors. Officers and others admitted as students will have the advantage of these courses of study, whether they reside or not. But officers and others who may not become students will, under certain regulations, have free access to separate courses of lectures, the benefit of which it is desired to extend as far as possible."

The following are the proposed courses of study:—

"1. Pure Mathematics, including co-ordinate and higher Pure Geometry, Differential Calculus, Finite Differences, and the Calculus of Variations. 2. Applied Mathematics, viz., Pneumatics, Mechanics, Optics, and the Theories of Sound, Light, Heat, Electricity, and Magnetism. 3. Applied Mechanics, including the Theory of Structures, the principles of Mechanism, and the Theory of Machines. 4. Nautical Astronomy, Surveying, Hydrography, with Maritime Geography, Meteorology, and Chart Drawing. 5. Experimental Sciences:—*a.* Physics, viz., Sound, Heat, Light, Electricity, and Magnetism; *b.* Chemistry; *c.* Metallurgy. 6. Marine Engineering, in all its branches. 7. Naval Architecture, in all its branches. 8. Fortification, Military Drawing, and Naval Artillery. 9. International and Maritime Law; Law of Evidence and Naval Courts Martial. 10. Naval History and Tactics, including Naval Signals and Steam Evolutions. 11. Modern Languages. 12. Drawing. 13. Hygiene—Naval and Climatic. A certain latitude in selecting such courses of study as they may prefer will be allowed to officers voluntarily attending the College. Officers and others required to attend by the Regulations will follow such courses of study as may from time to time be prescribed.

"The general organisation of the College will be as follows:—A flag officer will be president; he will be assisted by a captain in the Royal Navy in matters affecting discipline, and in the internal arrangements of the College unconnected with study. A director of studies will, under the president, organise and superintend the whole system of instruction, and the various courses of study. There will further be—A professor of mathematics, a professor of physical science, a professor of chemistry, a professor of applied mechanics, a professor of fortification. Such instructors in mathematics and the other branches specified as may be necessary to assist the professors will be added to the staff. Lecturers will be appointed to deliver courses of lectures in naval architecture, metallurgy, civil and hydraulic engineering, maritime law, naval history and tactics, and hygiene. A naval officer will conduct instruction in nautical astronomy and surveying, and there will be two instructors in steam. Such provision will be made for instruction in French and German and in drawing, as the number of students desirous of following courses in these branches may render necessary. . . .

"Arrangements have been made for the admission of naval engineer officers to the College, which will prevent time spent at the College from entailing any pecuniary loss upon them. The School of Naval Architecture at South Kensington will be absorbed in the Royal Naval College, Greenwich. The regulations for the admission of engineer students and of dockyard apprentices have been so framed as to provide as nearly as possible the same aggregate time for their instruction as that which is now afforded at South Kensington. Further regulations will be issued by their lordships in regard to the admission of private students to the course of study at the College on similar conditions to those now existing at South Kensington. My Lords have further determined to admit a limited number of officers of the Mercantile Marine as students of the College, enjoying the full advantages of the whole course of instruction and tuition by the educational staff, while officers of the Mercantile Marine generally will, on application, be allowed to attend courses of lectures.

"The paramount object which my Lords have pursued in the organisation of the College has been to provide the most efficient means for the higher education of naval officers adequate to the constantly increasing requirements of the service; but my Lords also anticipate great advantages from the results likely to accrue from the connection which will be established through the College between men distinguished in the various departments of mathematical, physical, and chemical science, and those practical problems which so vitally interest the navigator, the naval architect, and the naval engineer. My Lords expect the College to become, not only an educational establishment affording the means of the highest training in theoretical subjects to naval officers of all classes, but also a nucleus of mathematical and mechanical science specially devoted to those branches of scientific investigation which have most interest for the navy."

ELECTROSTATICS AND MAGNETISM

Reprint of Papers on Electrostatics and Magnetism. By Sir W. Thomson, D.C.L., LL.D., F.R.S., F.R.S.E., Fellow of St. Peter's College, Cambridge, and Professor of Natural Philosophy in the University of Glasgow. (London: Macmillan and Co., 1872.)

TO obtain any adequate idea of the present state of electro-magnetic science we must study these papers of Sir W. Thomson's. It is true that a great deal of admirable work has been done, chiefly by the Germans, both in analytical calculation and in experimental researches, by methods which are independent of, or at least different from, those developed in these papers, and it is the glory of true science that all legitimate methods must lead to the same final results. But if we are to count the gain to science by the number and value of the ideas developed in the course of the inquiry, which preserve the results of former thought in a form capable of being employed in future investigation, we must place Sir W. Thomson's contributions to electro-magnetic science on the very highest level.

One of the most valuable of these truly scientific, or *science-forming* ideas, is that which forms the subject of the first paper in this collection. Two scientific problems, each of the highest order of difficulty, had hitherto been considered from quite different points of view. Cavendish and Poisson had investigated the distribution of electricity on conductors on the hypothesis that the particles of electricity exert on each other forces which vary inversely as the square of the distance between them. On the other hand Fourier had investigated the laws of the steady conduction of heat on the hypothesis that the flow of heat from the hotter parts of a body to contiguous parts which are colder is proportional to the rate at which the temperature varies from point to point of the body. The physical ideas involved in these two problems are quite different. In the one we have an attraction acting instantaneously at a distance, in the other heat creeping along from hotter to colder parts. The methods of investigation were also different. In the one the force on a given particle of electricity has to be determined as the resultant of the attraction of all the other particles. In the other we have to solve a certain partial differential equation which expresses a relation between the rates of variation of temperature in passing along lines drawn in three different directions through a point. Thomson, in this paper, points out that these two problems, so different, both in their elementary ideas and their analytical methods, are mathematically identical, and that, by a proper substitution of electrical for thermal terms in the original statement, any of Fourier's wonderful methods of solution may be applied to electrical problems. The electrician has only to substitute an electrified surface for the surface through which heat is supplied, and to translate temperature into electric potential, and he may at once take possession of all Fourier's solutions of the problem of the uniform flow of heat.

To render the results obtained in the prosecution of one branch of inquiry available to the students of another is an important service done to science, but it is still more important to introduce into a science a new set of ideas, belonging, as in this case, to what was, till then, considered an entirely unconnected science. This paper of Thomson's, published in February 1842, when he was a very young freshman at Cambridge, first introduced into mathematical science that idea of electrical action carried on by means of a continuous medium which, though it had been announced by Faraday, and used by him as the guiding idea of his researches, had never been appreciated by other men of science, and was supposed by mathematicians to be inconsistent with the laws of electrical action, as established by Coulomb, and built on by Poisson. It was Thomson who pointed out that the ideas employed by Faraday under the names of Induction, Lines of Force, &c., and implying an action transmitted from one part of a medium to another, were not only consistent with the results obtained by the mathematicians, but might be employed in a mathematical form so as to lead to new results. One of these new results, which was, we have reason to believe, obtained by this method, though demonstrated by Thomson by a very elegant adaptation of Newton's method in the theory of attraction, is the "Method of Electrical Images," leading to the "Method of Electrical Inversion."

Poisson had already, by means of Laplace's powerful method of spherical harmonies, determined, in the form of an infinite series, the distribution of electricity on a sphere acted on by an electrified system. No one, however, seems to have observed that when the external electrified system is reduced to a point, the resultant external action is equivalent to that of this point, together with an imaginary electrified point within the sphere, which Thomson calls the *electric image* of the external point.

Now if in an infinite conducting solid heat is flowing outwards uniformly from a very small spherical source, and part of this heat is absorbed at another small spherical surface, which we may call a *sink*, while the rest flows out in all directions through the infinite solid, it is easy, by Fourier's methods, to calculate the stationary temperature at any point in the solid, and to draw the isothermal surfaces. One of these surfaces is a sphere, and if, in the electrical problem, this sphere becomes a conducting surface in connection with the earth, and the external source of heat is transformed into an electrified point, the sink will become the *image* of that point, and the temperature and flow of heat at any point outside the sphere will become the electric potential and resultant force.

Thus Thomson obtained the rigorous solution of electrical problems relating to spheres by the introduction of an imaginary electrified system within the sphere. But this imaginary system itself next became the subject of examination, as the result of the transformation of the external electrified system by reciprocal *radii vectores*. By this method, called that of electrical inversion, the solution of many new problems was obtained by the transformation of problems already solved. A beautiful example of this method is suggested by Thomson in a letter to M. Liouville, dated October 8, 1845, and published in *Liouville's Journal*, for 1845, but which does not seem to have been taken up by any mathematician, till Thomson himself, in a hitherto unpublished paper (No. xv. of the book before us), wrote out the investigation complete. This, the most remarkable problem of electrostatics hitherto solved, relates to the distribution of electricity on a segment of spherical surface, or a *bowl*, as Thomson calls it, under the influence of any electrical forces. The solution includes a very important case of a flat circular dish, and of an infinite flat screen with a circular hole cut out of it.

If, however, the mathematicians were slow in making use of the physical method of electric inversion, they were more ready to appropriate the geometrical idea of inversion by reciprocal *radii vectores*, which is now well known to all geometers, having been, we suppose, discovered and re-discovered repeatedly, though, unless we are mistaken, most of these discoveries are later than 1845, the date of Thomson's paper.

But to return to physical science, we have in No. vii. a paper of even earlier date (1843), in which Thomson shows how the force acting on an electrified body can be exactly accounted for by the diminution of the atmospheric pressure on its electrified surface, this diminution being everywhere proportional to the square of the electrification per unit of area. Now this diminution of pressure is only another name for that *tension* along the lines of electric force, by means of which, in Faraday's opinion, the mutual action between electrified bodies takes place. This short paper, therefore, may be regarded as the germ of that course of speculation by which Maxwell has gradually developed the mathematical significance of Faraday's idea of the physical action of the lines of force.

We have dwelt, perhaps at too great length, on these youthful contributions to science, in order to show how early in his career, Thomson laid a solid foundation for his future labours, both in the development of mathematical theories and in the prosecution of experimental research. Mathematicians however will do well to take note of the theorem in No. xiii., the applications of which to various branches of science will furnish them, if they be diligent, both occupation and renown for some time to come.

We must now turn to the next part of this volume, in which the mathematical electrician, now established as a Professor at Glasgow, turns his attention to the practical and experimental work of his science. In such work the mathematician, if he succeeds at all, proves himself no mere mathematician, but a thoroughly furnished man of science. And first we have an account of that research into atmospheric electricity which created a demand for electrometers; then a series of electrometers of gradually improving species; and lastly, an admirable report on electrometers and electrostatic measurements, in which the results of many years' experience are given in a most instructive and scientific form. In this report the different instruments are not merely described, but classified, so that the student is furnished with the means of devising a new instrument to suit his own wants. He may also study, in the recorded history of electrometers, the principles of natural selection, the conditions of the permanence of species, the retention of rudimentary organs in manufactured articles, and the tendency to reversion to older types in the absence of scientific control.

A good deal of Sir W. Thomson's practical electrical work is not referred to in this volume. It is to be hoped that he will yet find time to give some account of his many admirable telegraphic contrivances in galvanometers, suspended coils, and recording instruments, and to complete this collection by his papers on electrolysis, measurement of resistance, electric qualities of metals, thermo-electricity, and electro-magnetism in general.

The second division of the book contains the theory of magnetism.

The first paper, communicated to the Royal Society in 1849 and 1850, is the best introduction to the theory of magnetism that we know of. The discussion of particular distributions of magnetisation is altogether original, and prepares the way for the theory of electro-magnets which follows. This paper on electro-magnets is interesting as having been in manuscript for twenty-three years, during which time a great deal has been done both at home and abroad on the same subject, but without in any degree trenching upon the ground occupied by Thomson in 1847. Though in these papers we find several formidable equations bristling with old English capitals, the reader will do well to observe that the most important results are often obtained without the use of this mathematical apparatus, and are always expressed in plain scientific English.

As regards the most interesting of all subjects, the history of the development of scientific ideas—we know of few statements so full of meaning as the note at p. 419 relating to Ampères' theory of magnetism, as depending on electric currents, flowing in circuits within the molecules of the magnet; he goes on to say :—

> "From twenty to five-and-twenty years ago, when the materials of the present compilation were worked out, I had no belief in the reality of this theory; but I did not then know that motion is the very essence of what has been hitherto called matter. At the 1847 meeting of the British Association in Oxford, I learned from Joule the dynamical theory of heat, and was forced to abandon at once many, and gradually from year to year all other, statical preconceptions regarding the ultimate causes of apparently statical phenomena."

After a short, but sufficient, proof that the magnetic rotation of the plane of polarised light discovered by Faraday implies an actual rotatory motion of something, and that this motion is part of the phenomenon of magnetism, he adds :—

> "The explanation of all phenomena of electro-magnetic attraction or repulsion, and of electro-magnetic induction, is to be looked for simply in the inertia and pressure of the matter of which the motions constitute heat. Whether this matter is or is not electricity, whether it is a continuous fluid interpermeating the spaces between molecular nuclei, or is itself molecularly grouped; or whether all matter is continuous, and molecular heterogeneousness consists in finite vortical or other relative motions of contiguous parts of a body; it is impossible to decide, and perhaps in vain to speculate, in the present state of science."

The date of these remarks is 1856. In 1861 and 1862 appeared Maxwell's "theory of molecular vortices applied to magnetism, electricity, &c." which may be considered as a development of Thomson's idea in a form which, though rough and clumsy compared with the realities of nature, may have served its turn as a provisional hypothesis.

The concluding sections of the book before us are devoted to illustrations of magnetic force derived from the motion of a perfect fluid. They are not put forward as *explanations* of magnetic force, for in fact the forces are of the opposite kind to those of magnets. They belong more properly to that remarkable extension of the science of hydrokinetics which was begun by Helmholtz and so ably followed up by Thomson himself.

The conception of a perfectly homogeneous, incompressible frictionless fluid is as essential a part of pure dynamics as that of a circle is of pure geometry. It is true that the motions of ordinary fluids are very imperfect illustrstions of those of the perfect fluid. But it is equally true that most of the objects which we are pleased to call circles are very imperfect representations of a true circle.

Neither a perfect fluid nor a perfect circle can be formed from the materials which we deal with, for they are assemblages of molecules, and therefore not homogeneous except when regarded roughly in large masses. The perfect circle is truly continuous and the perfect fluid is truly homogeneous.

It follows, however, from the investigations of Helmholtz and Thomson that if a motion of the kind called *rotational* is once set up in the fluid, the portion of the fluid to which this motion is communicated, retains for ever, during all its wanderings through the fluid mass, the character of the motion thus impressed on it.

This *vortex* then, as Helmholtz calls it, be it large or small, possesses that character of permanence and individuality which we attribute to a material molecule, while at the same time it is capable, while retaining its essential characteristics unchanged both in nature and value, of changing its form in an infinite variety of ways, and of executing the vibrations which excite those rays of the spectrum by which the species of the molecule may be discovered. It would puzzle one of the old-fashioned little round hard molecules to execute vibrations at all. There was no music in those spheres.

But besides this application of hydrokinetics to this new conception of the old atom, there is a vast field of high mathematical inquiry opened up by the papers of

Helmholtz and Thomson. It is to be hoped that the latter will soon complete his papers on *Vortex Motion* and give them to the world. But why does no one else work in the same field? Has the multiplication of symbols put a stop to the development of ideas?

OUR BOOK SHELF

Natural History Transactions of Northumberland and Durham. Vol. IV. Part II. (Williams and Norgate.)

THIS volume of upwards of 250 pages confirms the reputation already attained by the Tyneside Naturalists' Field Club, as being one of the most efficient provincial scientific societies in the kingdom. Nearly all the papers are of real and permanent value, and it is to be hoped that ere long some means will be found of bringing the work of this and similar societies before a larger public than is likely to be reached by "Transactions," which are seldom seen by any but the members or their friends. A large part of the volume is devoted to the excellently compiled Meteorological Reports for 1870 and 1871, by the Rev. R. F. Wheeler, M.A. There is here much valuable material, more interestingly and artistically put together than such reports usually are. Mr. T. J. Bold contributes a well-arranged catalogue of 151 species of *Hemiptera-Heteroptera* of Northumberland and Durham. Mr. Bold contributes besides many valuable notes on various other kinds of insects found in the district so well worked by the Tyneside society; Mr. Bold deserves the highest credit for the quantity and quality of his work. Messrs. A. Hancock and T. Atthey describe a considerable portion of a Mandibular Ramus of *Anthracosaurus Russelli* (Huxley), found in the new ironstone shale of Fenton; they also add some notes on *Loxomma Almanni* (Huxley), and on some additional remains of *Archichthys Sulcidens* (Hancock and Atthey), recently found at Newsham. The same gentlemen contribute a few remarks on *Dipterus* and *Ctenodus*, and on their relationship to *Ceratodus Forsteri* (Krefft). A well-arranged list of the non-parasitic marine *Copepoda* of the north-east coast of England is Mr. G. S. Brady's contribution to the volume. The President's address, consisting mainly of a graphic account of the numerous club excursions during 1871, is the last paper in the volume, one of the most valuable features of which is the numerous and carefully executed lithographs which are appended. Nearly every paper is illustrated. Altogether it is a thoroughly satisfactory specimen of work.

LETTERS TO THE EDITOR

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. No notice is taken of anonymous communications.*]

Phosphorescence in Fishes

THE only reliable observations of active phosphorescence in fishes during life, known to the writer, are the following, to which, perhaps, may be added, the somewhat obscure observations on *Hemiramphus lucens*, communicated to G. Cuvier by Reinwardt:—

1. The observations of the two Bennetts ("Whaling Voyage" and "Gatherings in Australia") on a small luminous shark (*Squalus fulgens: Isistius brasiliensis*, Q.G.). (Perhaps also observed by Giglioli.)

2. The observations of J. Bennett on the luminosity of *Scopelus stellatus* (*l.c.*).

3. The luminosity of the head of *Astronesther niger* observed by Reinhardt (Videnskab. Meddel. f.d. naturhist. Forening: Kjöbenhavn, 1853).

Very probably the faculty is widely diffused among *Scopeloids* (*sensulatiore*), and Dr. Günther may be quite right in speaking of certain enigmatical organs in the skin of these fishes as their "luminous phosphorescent organs."

In Mr. Saville Kent's very sensible remarks on the phosphorescence (erroneously ascribed to several other fishes), in vol. vii. p. 47 of NATURE, I find a statement that startled me a little, viz., that "it has been proved beyond doubt that certain fish, *Cyclopterus lumpus*, for instance, do possess highly luminous properties" (during life, of course, or Mr. S. K. would not have mentioned it at all in this connection). I think that the observations regarding *Cyclopterus lumpus*, upon which this statement is based, are unknown to other zoologists than the writer, and that they would be much obliged to Mr. S. K. for a reference to his source of information.

Z.

Movements of the Earth's Surface

IT is, I believe, commonly supposed by geologists that the movements of the surface of the earth are caused by the refrigeration and contraction of the interior. But since the glacial epoch the surface of the earth has become warmer; consequently since that time a heat wave must have been passing from the surface towards the centre; and consequently since that time no refrigeration nor contraction of the interior can have taken place. If, therefore, movements of the earth's surface were due to this cause only, no such movements should have taken place since the glacial epoch.

F. W. HUTTON

Wellington, New Zealand, Nov. 10, 1872

Meteor Observed at Mauritius

ON Nov. 7 last, about 7 o'clock. P.M., I saw the most beautiful meteor fall that I ever remember observing in my life. My face was turned in the opposite direction, but an unusually brilliant and sudden flash of light, above the brightness of the moonshine, caused me to turn suddenly round in the direction the effulgence came from, and I saw a very large meteor majestically falling through the distance, seemingly of about eight or ten yards. I am not much of an astronomer, but I think it must have fallen, apparently, from some point in Aquarius. What particularly struck me in its appearance was that it was beautifully distinct, and round as the full moon, but seemingly about the ⅕th of a diameter larger. I ought, perhaps, rather to compare it to the moon at the end of her first quarter. [See p. 231 of this Number.]

A quarter of its disc only was luminous and brilliant, while the upper three-quarters emitted no luminosity, being of a dull, dusky, stone-brown colour. Here the circular outline was perfectly distinct, while the brightness of the lower limb took away all distinctness of outline there, making it appear slightly more prominent, besides throwing beyond the outline of the meteor itself a beautiful soft, steady, very bright radiance of a bluish white tint, which illuminated momentarily the whole heavens. It was observed by other people, and one person described to me having seen a similar meteor fall about this time last year, the disc appearing "about the size of a saucer," entirely luminous, but then no moon was shining.

W. WRIGHT

Moon's Surface

MAY not the white, telescopic appearance of the moon's surface, resembling snow in many parts, be explained by the fact that the extinct volcanoes of our satellite are covered with crystals of salt?

Any person who is accustomed to view the moon through a telescope must, I think, have been struck with the dazzling snow-white appearance of the mountains. May not an explanation of this be deduced from the experiences gained by the last eruption of Vesuvius?

"One of the most curious phenomena observed is the power of burning lava to retain an enormous quantity of water and salt, which it does not allow to escape till it begins to cool. . . . The formation of salt is shown generally over the whole stretch of lava emitted in 1872. Soon after the surface cools it is covered with a light crust of salt."—*See* NATURE, vol. vii. p. 2.

Is it not, therefore, probable that the numerous lava beds of the extinct volcanoes in our satellite may be coated with salt, bleached to the whiteness of snow?

C. H. W. MERLIN

British Consulate, Athens, Nov. 23